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EFFECTS OF DRIP IRRIGATION AND NITROGEN FERTILIZATION ON VEGETATIVE GROWTH, FRUIT YIELD, AND MINERAL COMPOSITION OF THE PETIOLES AND FRUITS OF PAPAYA

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INTRODUCTION

A recent commercial planting of papaya in Pulehu, Island of Maui, Hawaii, presented this opportunity to study the water and nitrogen requirements of papaya plants. The orchard, on the slopes of Haleakala at an elevation of 600 to 800 feet, is in an area where the days are warm, the nights are cool, rainfall is sparse, and the wind is strong at times. The soil has a low moisture-retention capacity. Under such conditions, papaya plants need to be intensely irrigated to maintain growth and production of fruits.

Information on the requirement of papaya plants for water is meager. In the only study conducted in Hawaii (*2*), papaya plants at Waimanalo, Island of Oahu, were irrigated by furrows, and the effects of soil moisture tension on growth and fruit yield were observed. Because it has been demonstrated that water is delivered to the roots of plants more efficiently by drip irrigation than by any other method, the drip method is being adopted by many crop growers in Hawaii and elsewhere (*1*).

In the present study, under drip irrigation, the water and nitrogen requirements of bearing papaya plants at Pulehu were tentatively determined. The effects of these variables on vegetative growth, fruit yield, and mineral composition of the petioles and fruits were also studied.

MATERIALS AND METHODS

This study was conducted on flowering and bearing papaya plants (*Carica papaya* L. variety 'Solo') at Princess Orchard, located at Pulehu, from September 1975 to June 1977. The soil in the orchard is in the Keahua series and is a member of the clayey, kaolinitic, isohyperthermic family of Typic Torrox, order of Oxisols (*10*). The available moisture of this soil was reported as being 4.5 percent (*10*), which indicates a low moisture retention capacity.

The experimental area was previously planted once with papaya. The soil was limed to about pH 6.7 with finely crushed coral 9 months prior to planting. Nitrogen (N) at 0.04 lb and phosphorus (P) at 0.05 lb from diammonium phosphate (18.46) were applied at the bottom of each planting site, and three young plants were transplanted into it. Plants were spaced 6 feet in a row, 5½ feet between rows 1 and 2, and 11 feet between rows 2 and 3, giving 880 plants/acre. At flowering, two out of three plants from a site were cut and discarded, and P at 0.20 lb/tree from treblesuperphosphate was applied equally in four shallow holes in the soil area around the drip line of the remaining tree. Thus, a total of 0.25 lb P/planting site was applied in this study.

Plants were subjected to 5 irrigation and 5 N treatments in a split-plot arrangement with the irrigation being the main plot and N the subplot, giving a total of 25 treatments. Each subplot consisted of six plants, three each from two adjacent rows, but data were taken from the two central plants of each plot only. Treatments were replicated twice in a randomized block design.

The nominal irrigation treatments, which were used to calculate the actual treatments, were water applied to each plant at 3, 6, 9, 12, and 15 gal/day. In an effort to maintain the relative effect of treatments throughout the year, a scheme was devised in which more water than the nominal treatments was given when the needs of the plants were greater and less water when the needs were less. The evaporation of water from a United States Department of Agriculture Class A pan was used as the basis of this weekly adjustment of water application. Thus, the weekly irrigation application of each treatment was the nominal treatment adjusted with the weekly pan evaporation of the water to correspond to the fraction of the average annual pan evaporation (1.637 inches/week). Plants were irrigated twice a week but the amount of water application was expressed on a per-day basis.

Plants were irrigated with a single microtube that was placed on the ground about 18 inches from the stem. The rate of water application was 8.7 gal/hour, equivalent to 10 lb/inch^2 in the water pressure gauge. Thus, differential treatments resulted from the duration of irrigation. When fields in the orchard were irrigated simultaneously with the experimental plots, however, the pressure of the water became lower, resulting in less amount of water delivery than the calibrated amount. During our study it was estimated that the occasional drop in water pressure resulted in 6 to 25 percent, or an average of 16 percent less water delivered than under more ideal conditions when water pressure was constant. The average estimated delivery of water (84 percent) was used for calculating the irrigation treatments. Thus, the average amounts of water (gallons) applied per tree per day during the course of this study were treatment 1, 2.7; treatment 2, 5.4; treatment 3, 8.1; treatment 4, 10.8; and treatment 5, 13.6. These will be referred to as I1, I2, I3, I4, and I5, respectively.

Nitrogen treatments were 0.10, 0.25, 0.50, 1.00, and 2.00 lb N/tree, and increments of these totals were applied at 6-week intervals from the flowering stage through 7 months of the bearing stage. Hereafter, these treatments will be referred to as N1, N2, N3, N4, and N5, respectively. Ammonium sulfate, the N carrier, was broadcast on the ground area in the vicinity of the microtube.

The growth rate of the stem circumference and the dry weight of the recently matured petiole, which was also used for chemical analysis of the nutrients, were used as the growth indices.

Mature fruits were harvested weekly from January 1976 to June 1977. At each harvest, they were segregated into marketable fruits (Hawaii Grade No. 1 export) and culls, and the number and weight of each group of fruits were recorded. Since response to the treatments was not detected in yield taken between January 13 to June 22, 1976, the total yield data from only June 29, 1976 to June 28, 1977 were statistically analyzed and presented in this report.

Fruits were sampled on September 2, September 30, October 28, and December 2, 1976, from the weekly harvest for fruit-quality and mineral determinations. A single marketable fruit per plot was sampled from harvested fruits and allowed to ripen at room temperature until a yellow color developed over 25 to 50 percent of the fruit surface. The firmness of the fruit flesh was then evaluated by using the University of California Firmness Tester. The total soluble solids and the moisture were

Table 1. Effects of irrigation and N fertilization on growth rate of the stem circumference

Treatment	Growth rate (mm/day)						
	Sept. 9, 1975– Dec. 2, 1975	Dec. 2, 1975– Feb. 24, 1976	Feb. 24, 1976– May 18, 1976	May 18, 1976– Aug. 10, 1976	Aug. 10, 1976– Nov. 4, 1976	Nov. 4, 1976– Jan. 25, 1977	Jan. 25, 1977– April 29, 1977
I1	0.85	1.51	0.92	0.04	0.01	0.13	0.05
I2	1.07	1.64	0.92	0.04	0.05	0.09	0.07
I3	1.00	1.71	1.05	0.07	0.02	0.10	0.06
I4	1.32	1.67	0.92	0.10	0.07	0.14	0.05
I5	1.30	1.74	1.02	0.09	0.06	0.12	0.08
Statistical significance[z]							
Linear	**	**	NS	*	*	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS
N1	0.97	1.63	0.98	0.03	0.03	0.09	0.04
N2	1.03	1.69	1.00	0.07	0.03	0.09	0.06
N3	1.20	1.62	0.97	0.04	0.05	0.14	0.06
N4	1.12	1.64	0.98	0.10	0.02	0.12	0.06
N5	1.22	1.67	0.91	0.10	0.07	0.15	0.09
Statistical significance[z]							
Linear	**	NS	NS	**	NS	NS	**
Quadratic	NS	NS	NS	NS	NS	NS	NS

[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

determined on a longitudinal sample of the fruit flesh, and a nutrient analysis was then made from the dried sample used in the moisture determination.

The recently matured petioles were sampled on June 22, 1976, August 24, 1976, October 19, 1976, and January 11, 1977 for determination of nutrients. Two petioles, one from each tree in a plot, constituted a sample. The preparation of the samples for chemical analysis and the chemical procedures for the nutrients, except for some nutrients, are described in an earlier report (*8*). Sodium (Na) was determined by atomic absorption, chlorine (Cl) by the chloridometer, and boron (B) by the autoanalyzer, using Azomethine-H reagent for color development.

The procedures described in Snedecor and Cochran (*12*) were used for statistical treatment of the data. Since N treatments were unequally spaced, Grandage's procedure for calculating the orthogonal coefficients (*11*) in regression was used.

RESULTS AND DISCUSSION

Vegetative Growth

There was no interaction between irrigation and N on growth, fruit yield, and fruit-quality factors in this study. Few interactions were detected in petiole composition; thus, the main effects of treatments will be emphasized in this report. Small but statistically significant differences in growth rate of the stem circumference resulted from the irrigation and N treatments at some of the measurement periods (Table 1).

An item of interest in the irrigation treatments was the observation that the circumference growth rate was larger during the period of December 2, 1975 to February 24, 1976 than during the period of September 9 to December 2, 1975 even though plants in the former period were older and were expected to grow at a slower rate than those in the latter period. A greater increase in circumference growth rate also was observed in the period of November 4, 1976 to January 25, 1977 over the period of August 10 to November 4, 1976. A feature common in both instances was that the period of faster growth coincided with the period of heavier rain, shorter days, lower light intensity, lower air temperature, and higher humidity of the air.

Table 2. Effects of irrigation and N fertilization on dry weight of the petiole

Treatment	Dry weight of the petiole on sampling date (g/petiole)			
	June 22, 1976	Aug. 24, 1976	Oct. 19, 1976	Jan. 11, 1977
I1	10.1	4.9	5.2	7.9
I2	13.3	5.8	6.2	8.9
I3	14.0	7.3	5.5	8.4
I4	16.8	9.0	6.4	9.7
I5	15.5	9.2	7.7	9.3
Statistical significance[z]				
Linear	*	*	NS	NS
Quadratic	NS	NS	NS	NS
N1	9.8	4.6	4.5	7.2
N2	11.6	5.4	4.8	7.6
N3	14.4	6.7	5.6	8.7
N4	16.8	8.7	7.4	10.2
N5	17.1	10.7	8.7	10.6
Statistical significance[z]				
Linear	**	**	**	**
Quadratic	**	*	NS	NS

[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

The growth of stem height was not studied in this experiment, but plants from Princess Orchard seemed to be taller than plants at a comparable stage of maturity from Puna, Island of Hawaii, and from Waimanalo and Poamoho, Island of Oahu, which might have resulted from the occurrence of a longer period of dry days (without rain) at Princess Orchard than at the other localities.

Increases in dry weight of the petioles resulted from both the irrigation and N treatments, but the latter had greater effect on this index of growth (Table 2). These results from the N treatments confirm results reported previously (*3*) and, thus, establish the change in petiole weight as a reliable index of vegetative response to N fertilization.

Fruiting and Fruit Quality

Yield of marketable fruits became higher up to treatment I4 as irrigation was increased; a further increase in yield beyond this treatment was not attained with a higher application of irrigation (Table 3). These increases in marketable fruits, however, were accompanied by a higher yield of culls. The percentage of marketable fruits tended to increase up to treatment I4 as more water was applied to the plants, but this was not statistically significant. With increasing irrigation rates, fruit size significantly increased. The total soluble solids and the firmness of the fruits were not affected by irrigation.

Yield of marketable fruits increased only up to treatment N3 as N fertilization was increased; however, in contrast with the yield of marketable fruits, culls increased up to treatment N5 as more N was given to the plants. The total soluble solids of the fruits increased as more N was applied to the plants, confirming results of previous studies at Waimanalo (7) and Puna (*4*). Fruits became softer as N fertilization increased, a finding that may be of importance in shipment of papaya to the market.

Nutrient-Element Composition of the Petioles

To separate the effect on petiole composition of the irrigation treatment from the effect of rain, the nutrient values of samples obtained during the dry season (June 22, August 24, and October 19, 1976) were averaged and are presented separately (Table 4) from the nutrient values of samples during the wet season (January 11, 1977) (Table 5). Nitrogen in the petiole tended to decrease as irrigation was

Table 3. Effects of irrigation and N fertilization on fruiting and some fruit-quality factors[y]

Treatment	Marketable fruits (no./tree)	Marketable fruits (lb/tree)	Marketable fruits (%)	Culls (no./tree)	Culls (lb/tree)	Fruits harvested (lb)	Total soluble solids (% fresh weight)[y]	Pressure of flesh (lb)[y]
I1	33.6	30.6	28.2	85.6	61.1	0.767	12.0	8.0
I2	47.2	45.1	32.1	100.0	80.0	0.833	12.6	8.7
I3	46.5	45.2	31.5	101.0	81.1	0.864	11.8	8.8
I4	58.0	59.8	35.2	106.9	92.6	0.928	12.4	9.7
I5	60.3	59.0	35.0	111.8	97.2	0.913	12.3	9.0
Statistical significance[z]								
Linear	*	*	NS	**	**	*	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
N1	41.0	41.0	35.2	75.4	64.4	0.897	11.9	10.3
N2	43.6	42.6	32.0	92.8	72.1	0.833	12.1	9.1
N3	50.6	53.8	34.1	97.7	83.8	0.902	12.0	8.5
N4	55.0	50.5	32.9	112.2	90.6	0.842	12.5	8.5
N5	55.4	51.8	30.3	127.2	101.4	0.831	12.6	8.0
Statistical significance[z]								
Linear	**	NS	NS	**	**	NS	*	*
Quadratic	NS	NS	NS	**	**	NS	NS	NS

[y]Data on fruiting were taken during June 29, 1976 to June 28, 1977 and those on total soluble solids and pressure of the fruits were averaged from samples taken on September 2, September 30, October 28, and December 2, 1976.

[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

Table 4. Effects of irrigation and N fertilization on moisture and mineral composition of the petiole during the dry season[y]

Treatment	Petiole moisture (% fresh weight)	Dry weight									
		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Na (%)	Cl (%)	Mn (ppm)	B (ppm)
I1	89.4	0.99	0.22	4.73	1.41	0.64	0.62	0.11	1.70	46	22.3
I2	89.2	0.92	0.23	4.75	1.38	0.61	0.59	0.13	1.52	44	22.6
I3	88.9	0.90	0.24	4.54	1.53	0.61	0.62	0.16	1.50	44	22.9
I4	89.2	0.92	0.23	4.64	1.53	0.56	0.61	0.18	1.45	41	22.9
I5	89.1	0.91	0.24	4.76	1.53	0.55	0.56	0.16	1.47	42	23.7
Statistical significance[z]											
Linear	NS	NS	NS	NS	*	*	NS	**	**	NS	*
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS
N1	89.6	0.84	0.26	5.13	1.53	0.64	0.64	0.16	1.87	41	23.5
N2	89.3	0.84	0.25	4.91	1.53	0.61	0.67	0.16	1.71	42	23.0
N3	89.2	0.88	0.23	4.93	1.37	0.56	0.64	0.15	1.50	45	23.0
N4	88.8	0.97	0.21	4.31	1.46	0.54	0.54	0.14	1.30	43	22.3
N5	88.9	1.12	0.20	4.13	1.49	0.61	0.51	0.13	1.26	46	22.7
Statistical significance[z]											
Linear	**	**	**	**	NS	NS	**	*	**	NS	*
Quadratic	**	NS	*	**	NS	**	NS	NS	**	NS	*

[y]Nutrient concentrations were averaged from petioles sampled on June 22, August 24, and October 19, 1976.
[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

Table 5. Effects of irrigation and N fertilization on moisture and mineral composition of the petiole during the wet season[y]

Treatment	Petiole moisture (% fresh weight)	Dry weight N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Na (%)	Cl (%)	Mn (ppm)	B (ppm)
I1	89.8	1.16	0.30	4.67	1.72	0.49	0.52	0.12	1.98	46	23.8
I2	89.9	1.22	0.29	5.09	1.69	0.46	0.55	0.12	1.85	44	22.8
I3	90.0	1.17	0.29	4.96	1.58	0.39	0.52	0.13	1.64	43	23.5
I4	89.8	1.20	0.30	4.82	1.74	0.42	0.54	0.14	1.60	39	23.0
I5	90.2	1.21	0.30	5.08	1.55	0.39	0.54	0.14	1.65	40	23.3
Statistical significance[z]											
Linear	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N1	90.0	1.05	0.33	5.25	1.67	0.48	0.59	0.13	2.18	39	24.1
N2	90.4	1.14	0.30	5.14	1.66	0.42	0.55	0.14	2.08	37	23.3
N3	89.8	1.12	0.30	5.11	1.64	0.39	0.54	0.12	1.74	44	23.2
N4	89.9	1.27	0.27	4.74	1.70	0.43	0.50	0.13	1.52	45	23.2
N5	89.7	1.38	0.26	4.38	1.62	0.43	0.48	0.13	1.22	46	22.6
Statistical significance[z]											
Linear	*	**	*	**	NS	NS	**	NS	**	*	**
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS

[y]Nutrient values were from petioles sampled on January 11, 1977.
[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

increased, but this was not statistically significant (Table 4). Calcium (Ca) and B in the petiole increased with increasing irrigation rates during the dry season (Table 4). Since these two elements are considered to be immobile in the phloem and therefore not subject to recirculation (*9*), the necessity of maintaining an adequate irrigation for a sustained supply of these two elements for development of new tissues is indicated. Sodium in the petiole became higher while magnesium (Mg) and Cl became lower as irrigation was increased.

The effects of the irrigation treatments on petiole composition observed during the dry season disappeared with the onset of rain (Table 5). During the wet season, petiole moisture in the high-irrigation treatment increased, which may be related to dilution from greater growth of plants in the low-irrigation treatment. Greater growth of plants in the low- than in the high-irrigation treatment also resulted from rain in the study at Waimanalo (*2*). The concentrations of N, P, potassium (K), Ca, and Cl in the petiole were higher during the wet than during the dry season. Petiole P was in the high range during the dry season and became even higher and was in the excess range during the wet season. Sulfur (S) and Mg in the petiole were lower during the wet than during the dry season.

In general, the concentration of petiole N at Princess Orchard in the dry season (Table 4) was substantially lower than that observed at Puna, throughout the year (*4, 6*). This difference in petiole N between the two places may be related to a difference in climatic conditions, which resulted in different growth patterns, which, in turn, resulted in such contrasting petiole-N concentrations. Even at Princess Orchard, however, the concentration of petiole N became higher in the wet season (Table 5), which again may be related to a difference in climatic conditions in the dry and wet seasons.

The effect of N fertilization on the petiole composition of the other elements was similar in the dry season (Table 4) and the wet season (Table 5). Decreases in petiole concentrations of P, K, S, Cl, and B resulted from N fertilization. Because N has a large effect on vegetative growth, it is not possible to attribute these decreases to growth dilution or to ion antagonism, but because the decreases in petiole concentrations of K and Cl were so much larger than those of the other elements, antagonisms of N/K and N/Cl were possibly in part operative. Manganese (Mn) in the petiole increased with increasing N fertilization, confirming results reported previously (*6*).

Nutrient-Element Composition of the Fruits

In the dry season, the concentration of Ca in the fruits decreased with increasing irrigation rates (Table 6), which is opposite from the result found in the petioles (Table 4). This may have resulted from a greater effect of dilution from increased fruit size than from increased petiole size. Nitrogen in the fruits became higher and P became lower as N fertilization increased during the dry and wet seasons (Tables 6, 7), which is similar to the effects observed in the petioles.

The concentration of the elements was generally lower in the fruits than in the petioles, but differences were larger with some elements than with others (Tables 4, 6). The concentration of N or P in the fruits was 80 percent of the concentration in the petioles, while that of Ca was only 14 percent of the concentration in the petioles. The difference in concentrations of B, K, and Mg between the fruits and the petioles was intermediate between that of N and Ca.

Figure 1 presents the relation between the concentrations of N in the fruits and in the petioles. This relationship is curvilinear, particularly at the high concentrations of petiole and fruit N. It indicates that, under

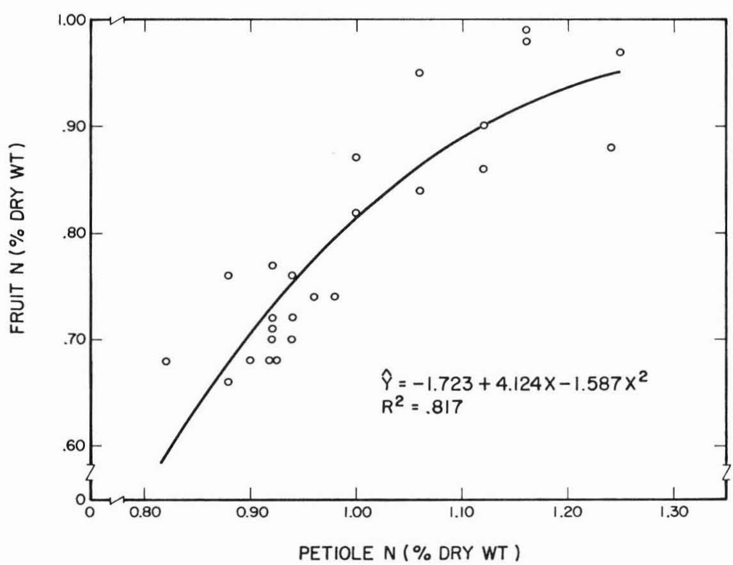

Figure 1. Relation of fruit N to petiole N. Petiole-N values from June 22, August 24, October 19, 1977, and January 11, 1978 and fruit-N values from September 3, September 30, October 28, and December 2, 1977 were averaged.

Table 6. Effects of irrigation and N fertilization on the mineral composition of the fruit during the dry season[y]

Treatment	Moisture (% fresh weight)	Dry weight N (%)	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)
I1	85.1	0.78	0.18	2.40	0.24	0.22	15.3
I2	85.3	0.78	0.18	2.31	0.22	0.20	15.4
I3	85.2	0.76	0.20	2.28	0.19	0.18	15.2
I4	85.3	0.76	0.20	2.30	0.17	0.17	14.6
I5	85.4	0.78	0.20	2.31	0.19	0.17	15.3
Statistical significance[z]							
Linear	NS	NS	NS	NS	**	*	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS
N1	85.8	0.70	0.23	2.43	0.21	0.20	15.3
N2	85.3	0.67	0.18	2.13	0.21	0.20	15.3
N3	85.3	0.70	0.20	2.32	0.21	0.19	14.9
N4	84.7	0.86	0.18	2.36	0.17	0.16	15.2
N5	85.3	0.92	0.16	2.37	0.22	0.20	15.2
Statistical significance[z]							
Linear	NS	**	**	NS	NS	NS	NS
Quadratic	**	NS	NS	NS	*	**	NS

[y]Nutrient concentrations from fruits sampled on September 3, September 30, and October 28, 1976 were averaged.
[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

Table 7. Effects of irrigation and N fertilization on the mineral composition of the fruit during the wet season[y]

Treatment	Moisture (% fresh weight)	Dry weight N (%)	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)
I1	84.8	0.86	0.25	2.96	0.27	0.23	14.9
I2	84.5	0.82	0.18	2.35	0.31	0.26	14.5
I3	84.8	0.88	0.22	2.51	0.33	0.25	14.9
I4	85.3	0.75	0.22	2.64	0.33	0.24	14.2
I5	84.6	0.87	0.19	2.34	0.32	0.25	13.9
Statistical significance[z]							
Linear	NS	NS	NS	**	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS
N1	86.2	0.80	0.28	2.74	0.39	0.30	15.4
N2	84.9	0.75	0.22	2.53	0.35	0.28	14.2
N3	84.8	0.79	0.22	2.57	0.27	0.22	14.6
N4	83.6	0.88	0.19	2.60	0.28	0.22	14.2
N5	84.5	0.94	0.16	2.35	0.26	0.21	14.0
Statistical significance[z]							
Linear	NS	**	**	NS	**	**	NS
Quadratic	*	NS	NS	NS	*	*	NS

[y]Nutrient concentrations were from December 2, 1976.
[z]Statistical significance: ** = 1% level, * = 5% level, and NS = not significant.

conditions at Princess Orchard, fruit N can be predicted from petiole N with a high degree of precision.

Relation of the Yield of Marketable Fruits to the Water Application Fraction of Pan Evaporation

The average weekly applications of water and the average pan evaporations of water during the summer of 1976 and the water applications as fractions of the pan evaporation are presented in Table 8.

In Figure 2 the yield of marketable fruits was related to the water application fraction of the pan evaporation. Maximum yield of fruits was attained at the water application fraction of 1.29. This value is 17 percent higher than the value reported for sugarcane and maize (*1*), which would place papaya in a higher category than these crops in its requirement for water.

Relation of the Number of Marketable Fruits to Petiole N

Because the concentration of petiole N from treatment I1 tended to be higher than that of petiole N from the other irrigation treatments and did not seem to belong in the same group as the others, petiole N from this treatment (I1) was not included in this phase of the study. The optimal number of marketable fruits was produced at about 0.86 percent N (Figure 3), which is considerably lower than the optimal number determined for Puna (*4, 6*) and Waimanalo (*7*). This difference in the critical N level between Princess Orchard on one hand and Puna and Waimanalo on the other may be related to a difference in growth conditions as discussed in previous sections of this report.

Table 8. Amount of water application in the various treatments expressed as a fraction of pan evaporation during the summer of 1976.

Treatment	Irrigation (inches/day/acre)^z	Pan evaporation (inches/day/acre)^z	Irrigation/ pan evaporation
I1	.115	.350	.33
I2	.227	.350	.65
I3	.348	.350	.99
I4	.452	.350	1.29
I5	.566	.350	1.62

^{z}Averaged from weekly data during June 29 to September 20, 1976.

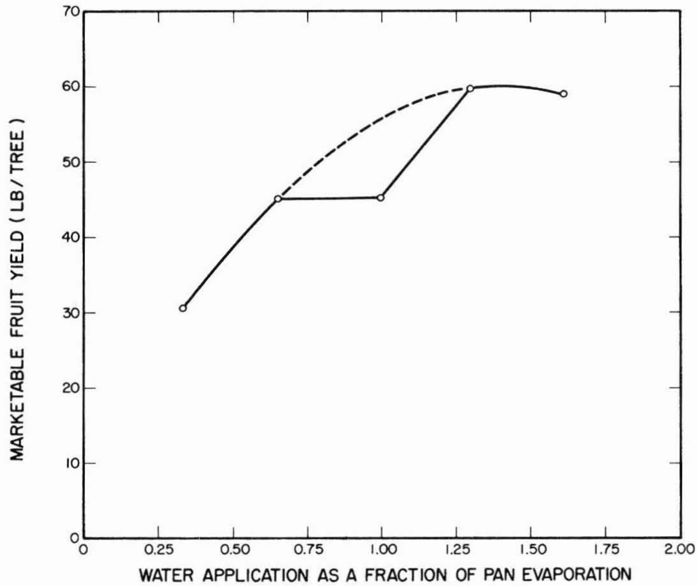

Figure 2. Relation between the yield of marketable fruits and the water application expressed as a fraction of pan evaporation. The datum of fruit yield was the total weekly yield from June 29, 1976 to June 28, 1977, and the datum of the water application was averaged from weekly data during June 29 to September 20, 1976 and expressed on a per-day basis.

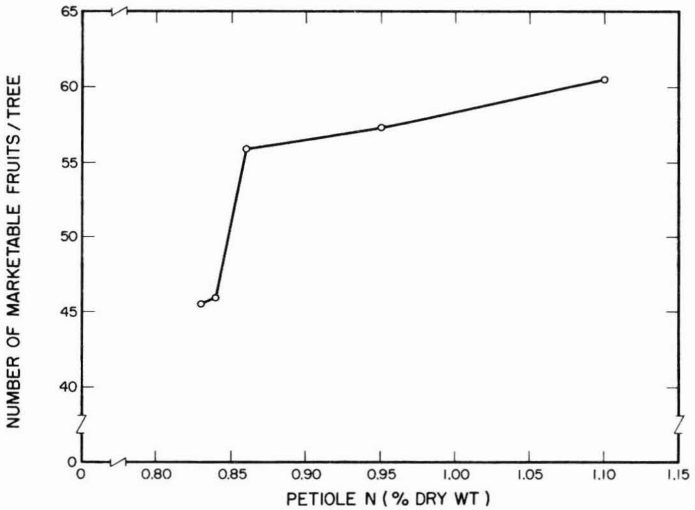

Figure 3. Relation between the number of marketable fruits and the concentration of petiole N. Yield was the total number of marketable fruits harvested from June 29, 1976 to June 28, 1977, and petiole N was averaged from the samples of June 22, August 24, and October 19, 1976.

RECOMMENDATIONS

Since an increase in irrigation resulted in an increased number and increased size of marketable fruits without affecting the total soluble solids and firmness of the fruits, an irrigation rate associated with maximum fruit yield is advisable at Princess Orchard. In scheduling irrigation for the week, the amount of water application should be 1.3 times the pan evaporation of water (Class A pan) from the previous week.

The concentration of petiole-N during the dry season at Princess Orchard should be maintained at about 0.86 percent N, dry weight. The application rate of N associated with this concentration of petiole N was a total of 0.50 lb N/tree applied in increments at 6-week intervals from the flowering stage through 6 months of the bearing stage. This application rate applies only to replant fields in Princess Orchard, which had a similar N fertilization schedule as the orchard used in the present study.

Since P at 224 lb/acre resulted in petiole-P concentrations in the high to excessive range, a rate of about 45 lb P/acre, applied at transplanting time only, is advisable. Potassium fertilizer was not applied in the present study and yet the petiole-K concentration was in the high range. Thus, this nutrient should be deleted from the fertilizer program at Princess Orchard until the need for it appears in the future.

Another study is needed at Princess Orchard to determine whether the critical-N concentration determined from petioles sampled during the wet season will be similar to the one at Puna. The experimental area should be in an area that is low in soil N, and the planting date should be so selected that N response is obtained at the start of bearing during the wet season. A study is also needed to determine the most suitable irrigation interval (number of days before irrigating) and the number of microtubes per plant for optimum delivery and distribution of water in the soil.

SUMMARY

Flowering and bearing papaya plants at Pulehu, Island of Maui, were differentially irrigated by the drip method and differentially fertilized with N in factorial combinations.

The growth rate of the stem circumference was increased at times by the irrigation and N treatments, but these increases were small. The weight of the petiole was increased consistently by N fertilization.

The yield, number, and size of the marketable fruits were increased by the irrigation rates. The number of marketable fruits was increased by the N fertilization, but this increase was accompanied by a high yield of culls. The total soluble solids of the fruits were increased, but the firmness of the flesh was decreased by the N fertilization.

The concentration of petiole N and the critical-N concentration during the dry season (June 22 to October 19) were substantially lower than those found in Puna, Island of Hawaii, and the explanation of this difference at the two places is discussed.

The concentrations of Ca, B, and Na in the petiole increased and those of Mg and Cl decreased as irrigation was increased. Nitrogen in the petiole tended to decrease as irrigation was increased, but this was not statistically significant. The concentrations of P, K, S, Cl, and B in the petiole decreased and the concentration of Mn increased as N fertilization increased.

The yield of marketable fruits was related to the water application fraction of the pan evaporation, and maximum yield was obtained at the water application fraction of 1.29. It is suggested that this value be used as a guide to irrigation of papaya plants at Pulehu, Maui.

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